**Resource Action: EWG-36** **Task Force Recommendation Category: 2**

# Operate the Oroville Facilities to Provide Additional Cold Water in the Low Flow Channel of the Feather River for Benefit of Chinook Salmon and Steelhead

**Description of Potential Resource Action Measure:**
This measure proposes to change operations of the Oroville Facilities to reduce water temperatures in the low-flow channel of the Feather River (LFC) during certain times of year for the benefit of Chinook salmon and steelhead. The changes in operation would likely include releasing colder water from the reservoir and increasing flow releases to the LFC. As formulated by the EWG, this Resource Action would most likely be implemented from April through October. This period includes the rearing period for spring-run Chinook salmon and steelhead, and the immigration, holding and spawning period for spring-run Chinook salmon.

**Date of Field Evaluation:** No field evaluation was conducted

**Evaluation Team:** Phil Unger, review by Brad Cavallo and Mike Manwaring

**Related Resource Actions:**
Other Resource Actions that are either similar to or otherwise related to this measure include:

- EWG-35A and EWG-35B, which propose to reduce rates of fish predation on juvenile salmonids by reducing water temperatures.
- EWG-37, which proposes to operate the Oroville Facilities in a manner that would provide colder water in Feather River downstream of the Thermalito Afterbay river outlet for benefit of Chinook salmon and steelhead.
- EWG-87, which proposes to modify the Thermalito Complex facilities in a manner to increase water temperatures in the Thermalito Afterbay and reduce temperatures in the Feather River downstream of the Afterbay outlet for beneficial uses.
- EWG-102, which proposes to provide water temperatures in the lower Feather River that mimic historic (pre Oroville Dam) river temperatures to help maintain the genetic integrity of the spring-run Chinook salmon.
- EWG-27, which proposes to fill, modify, or isolate Robinson Riffle Borrow Pit.

**Nexus to the Project:**
Water temperatures in much of the lower Feather River are strongly affected by operations of the Oroville Facilities. The Oroville Facilities allow project operators to regulate the depth in Oroville Reservoir from which water is released, the amount of water released from the reservoir into the river, the amount of water diverted from the LFC of the river through the Thermalito Complex, and the amount of water pumped

back into the reservoir from the Thermalito Complex. These operational controls give the operators various degrees of control over water temperatures in the LFC.

The 1983 agreement between DWR and DFG, Concerning the Operation of the Oroville Division of the State Water Project for management of Fish & Game, established quantitative water temperature criteria for the lower Feather River. In this agreement, the Oroville Project is required to meet quantitative water temperature criteria at two downstream locations: the Feather River Hatchery (FRH) and the LFC at Robinson's Riffle (River Mile 61.6). Generally speaking, the FRH water temperature criteria serve as the controlling water temperature targets because the Robinson's Riffle criterion is usually satisfied whenever the FRH criteria are met. The FRH criteria vary over the course of a year as shown in the following table:

| Period | Temperature (+/- 4°F) |
|---|---|
| April 1 – May 15 | 51° |
| May 16 – May 31 | 55° |
| June 1 – June 15 | 56° |
| June 16 – August 15 | 60° |
| August 16 – August 31 | 58° |
| September 1 – September 30 | 52° |
| October 1 – November 30 | 51° |
| December 1 – March 31 | 55° |

Table 1. Feather River Hatchery Water Temperature Requirements from Oroville Project Operations.

Deviations in FRH water temperature of 4$^{o}$F above or below the FRH criteria are allowed. The Robinson's Riffle criterion is a daily average water temperature less than or equal to 65$^{o}$F from June 1 through September 30.

**Potential Environmental Benefits:**
The EWG fisheries team determined Chinook salmon and steelhead water temperature needs for each life stage by synthesizing information obtained from the fisheries literature. Both fall-run and spring-run Chinook salmon spawn in the LFC beginning in early September (Table 2). The EWG team determined that spawning and egg incubation water temperature requirements for Chinook salmon are no more than 56$^{o}$F or 58$^{o}$F (the two values reflect minor differences in the set of literature sources used for deriving the critical temperature estimates). Steelhead begin spawning about December, but continue spawning until approximately April, and egg incubation can continue through May. The EWG team determined that spawning and egg incubation temperature requirements for steelhead are 52$^{o}$F and 54$^{o}$F (again, the two values reflect differences in the set of literature sources used for estimates). Spring run adults hold in pools in the LFC from late spring through summer and fall run migrate upstream in late summer and hold more briefly. The EWG team determined that upstream migration and holding temperature requirements for adult spring-run and fall-run Chinook salmon are

60°F and 64°F (as before, the two values reflect differences in the set of literature sources used for estimates).

| Life stage Activity/ Species or Run | Period | Upper Water Temperature Limit* |
|---|---|---|
| Spawning and Egg Incubation | | |
| Spring-run Chinook | September – mid February | 56°F & 58°F |
| Fall-run Chinook | September – mid February | 56°F & 58°F |
| Steelhead | December - May | 52°F & 54°F |
| Immigration and Holding | | |
| Spring-run Chinook | March - October | 60°F & 64°F |
| Fall-run Chinook | mid July - December | 60°F & 64°F |
| Steelhead | September – mid April | 52°F & 56°F |

* Two values reflect minor differences in literature sources used to derive temperature limits.

Table 2. Months and Temperature Limits of Chinook Salmon and Steelhead Lifestages.

The suitability of water temperature conditions in the LFC for salmon and steelhead was evaluated by comparing the water temperature limits in Table 2 to results of benchmark study water temperature modeling runs of existing (2001) conditions. The benchmark study simulates water temperatures at different locations based on current level-of-development hydrology and the current regulatory framework. The study estimates natural variability by using the 1922 through 1994 water year hydrology and meteorology for the water temperature simulations. Figures 1 through 4 present results of the study for three locations in the LFC: the Fish Barrier Dam, Robinson's Riffle and a site 0.4 miles upstream of the Thermalito Afterbay river outlet. The Fish Barrier Dam marks the upstream limit of the LFC, Robinson's Riffle is 5.55 river miles downstream of the Fish Barrier Dam, and the site upstream of the Thermalito Afterbay outlet is 7.85 river miles downstream of the dam. Figure 1 shows typical and extreme water temperatures for each location and month, as represented by the median of the daily average water temperatures, the 95$^{th}$ percentile of the daily maximum water temperatures and the 5$^{th}$ percentile of the daily minimum water temperatures. The figure also shows the most critical upper water temperature limits for each month, as described below. The results show that in all seven months, the median water temperature increases downstream from the Fish Barrier Dam to Robinson's Riffle and the site upstream of the Thermalito Afterbay outlet. Also, the median water temperatures at all three locations increase from April through August, and then decline. Figures 2 through 4 provide exceedance plots for daily average water temperatures in April through November at the three LFC locations.

Table 3 gives the frequencies, as percentages, that the salmon and steelhead water temperature limits are exceeded for each month from April through November at each of the three locations. These results are based on the temperature limits in Table 2 and the exceedance data in Figures 2 through 4. For each month from April through November, Table 3 gives the species/life history stage activity with the most restrictive (coldest) water temperature limits, the two water temperature estimates of those limits

from Table 2, and the percentage of days during each month that the daily average water temperature exceeds each limit. These percentages are provided for the three locations in the LFC; the Fish Barrier Dam, Robinson's Riffle and upstream of the Thermalito Afterbay river outlet. For September, October and November, the temperature limits and exceedance frequencies are provided for two species/life stage activities, spring-run and fall-run salmon spawning and egg incubation and steelhead immigration and holding. Although steelhead immigration and holding has colder water temperature requirements than salmon spawning and egg incubation, the latter are considered to be more critical because of the greater sensitivity of spawning and egg incubation to unsuitable water temperature conditions.

| Month | Limiting Species/Life Stage* | Upper Temperature Limits ($^{o}$F)** | Frequency of Exceeding Limits (%) | | |
|---|---|---|---|---|---|
| | | | Fish Barrier Dam | Robinson's Riffle | Above TAO |
| April | SH S&E | 52 and 54 | 7 and 2 | 50 and 20 | 73 and 38 |
| May | SH S&E | 52 and 54 | 35 and 8 | 89 and 64 | 96 and 82 |
| June | SR I&H | 60 and 64 | 0 and 0 | 25 and 2 | 49 and 11 |
| July | SR & FR I&H | 60 and 64 | 4 and 0 | 56 and 6 | 81 and 29 |
| August | SR & FR I&H | 60 and 64 | 15 and 0 | 82 and 15 | 97 and 42 |
| September | SR & FR S&E;<br>SH I&H | 56 and 58;<br>52 and 56 | 40 and 13;<br>84 and 40 | 84 and 63;<br>100 and 84 | 95 and 79;<br>100 and 95 |
| October | SR & FR S&E;<br>SH I&H | 56 and 58;<br>52 and 56 | 9 and 2;<br>74 and 9 | 45 and 19;<br>95 and 45 | 59 and 32;<br>97 and 59 |
| November | SR & FR S&E;<br>SH I&H | 56 and 58;<br>52 and 56 | 9 and 0;<br>66 and 9 | 21 and 6;<br>79 and 21 | 29 and 12;<br>82 and 29 |

* SH=steelhead, SR=spring-run chinook, FR=fall-run chinook, S&E=spawning and egg incubation, I&H=immigration and holding
** Two values reflect minor differences in literature sources used to derive temperature limits.

Table 3. Frequencies of Exceeding Temperature Limits of Limiting Species/Life Stage during each Month based on Benchmark Study Simulation Results

The results in Table 3 show that the temperature limits are sometimes exceeded in almost every month and location in the LFC. However, there are large differences in the exceedance frequencies among the locations. Other than the steelhead immigration and holding temperature limits, the limits are satisfied at the Fish Barrier Dam more than 50% of the time in every month, and in most months they are satisfied at least 90% of the time. At Robinson's Riffle, which typically is substantially warmer than the Fish Barrier Dam location during the late spring through early fall period (Figure 1), the frequencies of exceeding the temperature limits are consistently higher. They are especially high in May, August and September. At the site upstream of the Thermalito Afterbay outlet, the temperature limits are exceeded more than half of the time in most months. More specifically, April and May water temperature conditions are generally unsuitable for steelhead spawning and egg incubation at the two downstream locations in the LFC, and the same is true of September and October water temperature conditions for salmon spawning and egg incubation. Summer water temperatures are generally suitable for salmon immigration and holding only at the upstream location.

This finding is consistent with results of the relicensing study, SP F10, Task 1E, which concluded that summer water temperatures in the upstream portion of the LFC near the Fish Barrier Dam are suitable for spring run holding, but water temperatures in the downstream portion of the LFC are generally not consistently suitable for spring run holding.

It should be noted that the frequencies of occurrence should not be equated to probabilities because water temperatures on a given day are not independent events, but rather tend to be related to temperatures on neighboring dates. As a result, water temperatures of a month within a year tend to be more similar than those of the same month in other years. This is significant because it means that the probability of exceeding a temperature limit every year is actually somewhat lower than suggested by the frequencies in Table 3. Nevertheless, the results clearly indicate that reducing water temperatures in the LFC, particularly in the more downstream portions of the LFC, would benefit salmon and steelhead.

Although the salmon and steelhead water temperature limits are frequently exceeded at the two downstream locations in the LFC, the level of exceedance is usually relatively small. As shown in Figure 1, the median water temperatures at Robinson's Riffle and the above-Thermalito site are generally within a degree or two of the temperature limits. Although water temperatures occasionally exceed the limits substantially, as indicated by the 95$^{th}$ percentiles of the maximum water temperatures, such extreme water temperature conditions are by definition rare. These results suggest that much of the time only minor changes in project operations would be required to satisfy the water temperature requirements of salmon and steelhead.

**Potential Constraints:**
As previously noted, this Resource Action would likely include releasing colder water from Oroville Reservoir and/or increasing flow releases to the LFC. However, several important potential constraints could limit these changes in operations. The most immediate potential constraint is the requirement to meet the FRH water temperature criteria. Releasing colder water from the reservoir could cause water temperatures to drop below the criteria. However, because the reductions in water temperature required for this measure would often not be large, this potential constraint would probably only occasionally affect the implementation of the Resource Action.

A major potential constraint on this measure is the need to maintain current Oroville Project contributions to the statewide water supply. The Oroville Project is one of many water projects coordinated to meet California's water supply needs. Releases from the different storage reservoirs of the State Water Project and Central Valley Project are carefully managed in a coordinated fashion to satisfy irrigation, municipal and environmental demands without unduly risking future supplies. The amount of water released from Oroville Reservoir cannot be substantially altered without disrupting this system. Increasing Oroville Project deliveries at one time would generally require reductions in deliveries at other times, and such reductions could be mitigated only by

requiring other water projects to increase their deliveries or by reducing demand. The Oroville Project cannot reduce demand or alter the delivery schedules of other water projects. If the total releases from the Oroville Facilities cannot be changed, the amount of flow released into the LFC can be increased only by reducing diversions to the Thermalito Complex.

The amount by which diversions to the Thermalito Complex can be reduced is limited because of the water rights of farmers that divert from the Complex. At times, the irrigation demands of these farmers consume all but about 800 cfs of the flow released from Oroville Reservoir, so no more than 800 cfs is available for release to the LFC (Olson 2004). More flow could be released to the LFC when the reservoir releases exceed the irrigation demands by more than 800 cfs, but such increases would result in fluctuations in LFC flow, which could adversely affect habitat in the LFC. This and other factors discussed below constrain increases in LFC flow in many years, except for flood control purposes.

In addition to being constrained by water supply considerations, substantial increases in LFC flows are constrained by habitat considerations. Instream flow studies of fish habitat (PHABSIM) indicate that the availability of spawning habitat for Chinook salmon and steelhead in the LFC are maximized at a flow of about 800 cfs. Therefore, water temperature benefits potentially gained by increasing LFC flow above 800 cfs could be offset by habitat reductions.

Another major constraint on this Resource Action is the limited volume of Oroville Reservoir's cold-water pool. The limited volume of cold water in the reservoir restricts how much and for how long water temperatures in the LFC could be reduced. This constraint would be particularly significant in dry and critically dry water type years.

The loss of generation that would likely accompany implementation of the measure is another important potential constraint on this measure. Operations that can be used to reduce water temperatures in some or all of the LFC include increasing flow releases to the LFC (as previously discussed), reducing pump-back and peaking operations, and opening the Oroville Dam river valve. These actions would typically result in losses in hydroelectric power generation.

This measure could also be constrained by regulatory requirements. A narrative objective for water temperatures in the Feather River below the Thermalito Afterbay river outlet requires water temperatures that are suitable for shad, striped bass and other warmwater species from May through August. Reducing spring and summer water temperatures in the LFC could make it difficult to meet this objective. Measures to reduce water temperatures in the LFC are also potentially constrained by the goal to supply rice farmers with warm water during spring and summer and by the goal to provide suitable warm water for recreation activities.

**Existing Conditions in the Proposed Resource Action Implementation Area:**
The LFC is situated downstream of the Oroville Dam, extending about eight miles from the Fish Barrier Dam to the Thermalito Afterbay outlet. The average monthly water temperatures in the LFC near the Fish Barrier Dam typically range from about 46°F in winter to about 58°F in summer. Water temperatures typically drop sharply from August to September (Figure 1), largely because the FRH water temperature criterion for September is much lower than that for late August (52$^{o}$F vs. 58$^{o}$F).

Water temperatures in the upstream end of the LFC are generally determined by the FRH temperature requirements, while water temperatures at downstream locations are determined by whatever warming or cooling occurs in the LFC as the water flows downstream from the Fish Barrier Dam. Results of the benchmark study water temperature modeling runs were used to assess rates of warming in two reaches of the LFC during April through October. The upper reach, from the Fish Barrier Dam to Robinson's Riffle, is 5.55 miles long and the lower reach, from Robinson's Riffle to the site upstream of the Thermalito Afterbay Outlet, is 2.3 miles long. Rates of warming are generally similar between the two LFC reaches, with increases in median average daily water temperatures ranging from about 0.5$^{o}$F per river mile during April and October to about 0.8$^{o}$F per river mile during June and July (Figure 5). Because of the difference in the length of the two reaches, total warming in the upper reach is considerably greater than that in the lower reach (see Figure 1).

During extreme years, water temperature increases in the LFC are substantially greater than those described above. The 95$^{th}$ percentile increase was about 1.25$^{o}$F per river mile in the lower reach during July and in both reaches during June (Figure 5). The June increases result in a total increase for the LCF of about 10$^{o}$F (7.06$^{o}$F in the upper reach and 2.98$^{o}$F in the lower reach).

Because of the influence of warm water inflow from the Thermalito Afterbay outlet, water temperatures in the Feather River just downstream of the outlet are often several degrees warmer than temperatures in the lower part of the LFC. At times, back flow from the Thermalito Afterbay outlet and warm water released from Robinson Pond may contribute to temperature increases in the final mile of the LFC. The sudden increase in water temperature at the Thermalito Afterbay outlet may be stressful for migrating fishes, and also elevates predation risk because of the increased abundance of piscivorous bass and Sacramento pikeminnow, which are less tolerant than the salmonids of the cold water temperatures in the LFC.

**Design Considerations and Evaluation:**
Engineering and Operations water temperature modelers are currently evaluating effects of different project operations on water temperatures in the LFC. Results of the modeling simulations will be used to develop specifics of how project operations could be modified to implement this Resource Action.

The effectiveness of this measure would be evaluated by comparing water temperatures measured at several locations in the LFC before and after implementing the measure. The comparisons would use water temperature modeling to adjust for differences in atmospheric conditions and other potentially confounding variables in making the comparisons. Water temperature data currently being collected in the LFC will provide the information on water temperatures before implementing any changes in project operations.

**Synergisms and Conflicts:**
This Resource Action is compatible with Resource Actions EWG-37 and EWG-102, which share with EWG-36 the resource goal of providing desirable water temperatures for coldwater fish. By benefiting coldwater fishes, the Resource Action would likely enhance recreation in the LFC, providing increased summer angling opportunities for trout and Chinook salmon. This Resource Action would enhance improve habitat conditions for anadromous salmonids and potentially improve upstream passage through the fairly steep thermal gradient at the end of the LFC, which are resource goals of many of the proposed resource actions. The colder water that would result from this resource action might also help reduce predation on juvenile salmonids in the Thermalito Pool, upstream of the Afterbay outlet, because colder water in the Pool would reduce metabolic rates of the fish predators in the Pool, and thereby potentially reduce their feeding rates. Reduced predation on juvenile salmonids is the basis for Resource Actions EWG-35A, EWG-35B and EWG- 27.

This Resource Action would potentially conflict with a number of resource goals. These include providing warmer water to Thermalito Afterbay for agriculture (e.g., EWG-87), increasing production of coldwater fishes in the reservoir, and enhancing water contact recreational opportunities in the lower Feather River. Depending on the methods used to reach desired temperatures, this resource could also have considerable costs in terms of lost power generation. However, to the extent that more water is diverted through the LFC rather than through the Thermalito Complex, this resource action also has the potential to allow warmer waters for agricultural diversion from the Thermalito Afterbay (EWG-87).

**Uncertainties:**
Important uncertainties related to this measure include:

- Whether the amount of water in Oroville Reservoir's cold-water pool during dry and/or critically dry years would be sufficient to effect the proposed reductions in water temperatures, particularly during late summer and fall, and how a reduction in the volume of the cold-water pool would affect the cold-water fisheries of the reservoir.
- Whether the Resource Action could be implemented without conflicting with DWR agreements or goals, including the FRH water temperature criteria, the goal to provide suitable water for the needs of rice farmers, and the agreement to provide water temperatures downstream of the Thermalito Afterbay outlet from

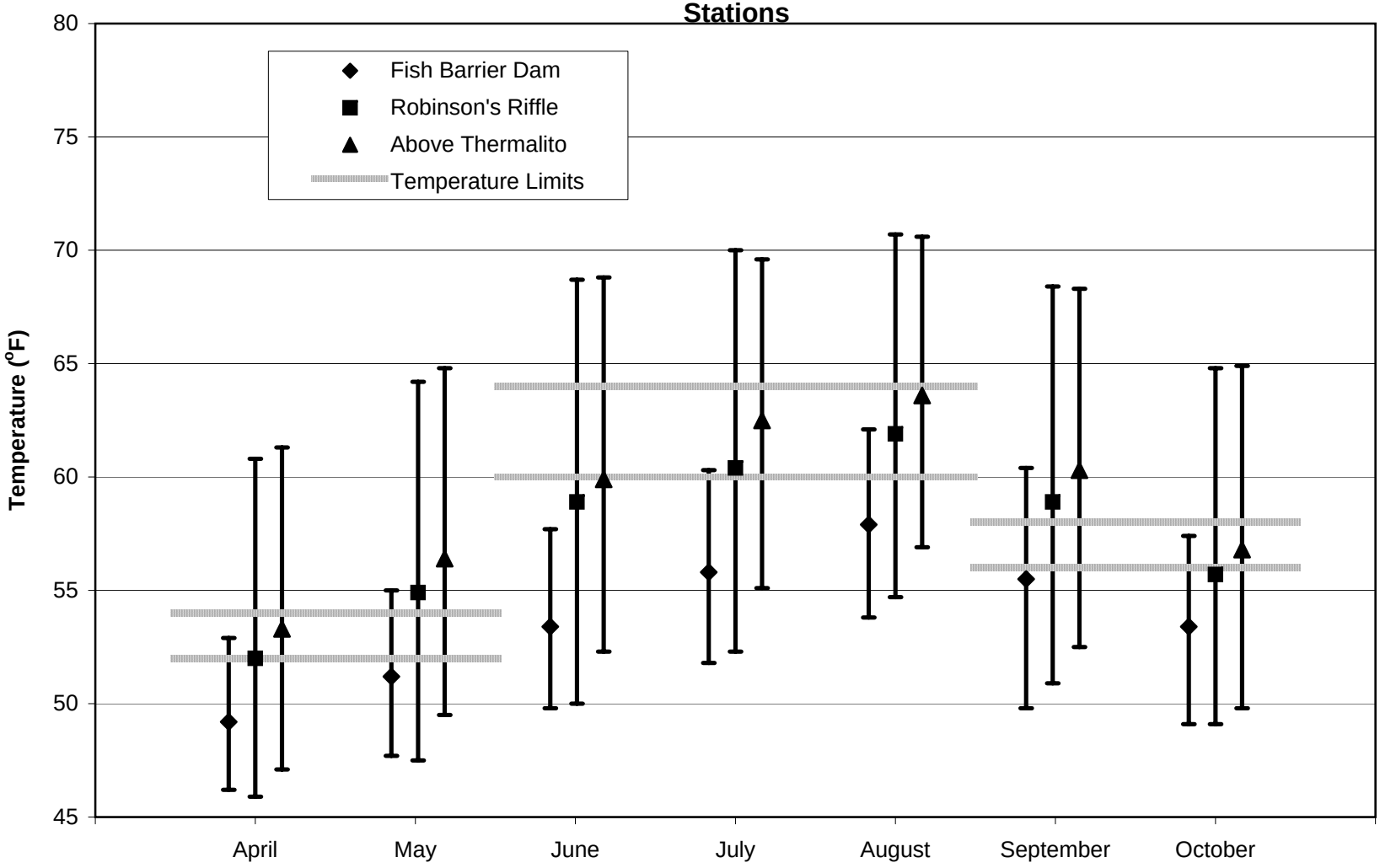
May through August that are suitable for shad, striped bass and other warmwater species.

- The amount of revenue that would be lost because of changes in power generation.

**Cost Estimate:**
The principle cost of this measure would be lost revenues associated with the changes in power generation (including reduced generation and changes in generation peaking). Additional costs would come from water temperature monitoring to evaluate the effectiveness of the measure and to ensure compliance with any new water temperature requirements.

**Recommendations:**
Before implementing this measure, additional information is needed from water temperature modeling simulations. These evaluations should provide useful insights on the feasibility of the measure in light of the potential conflicts and limitations.

**Figure 1. Median of Daily Average, 95th Percentile of Daily Maximum, and 5th Percentile of Daily Minimum Water Temperatures for Benchmark Study Conditions; Low Flow Channel Stations**



**Oroville Facilities Relicensing Efforts**
**Environmental Work Group**

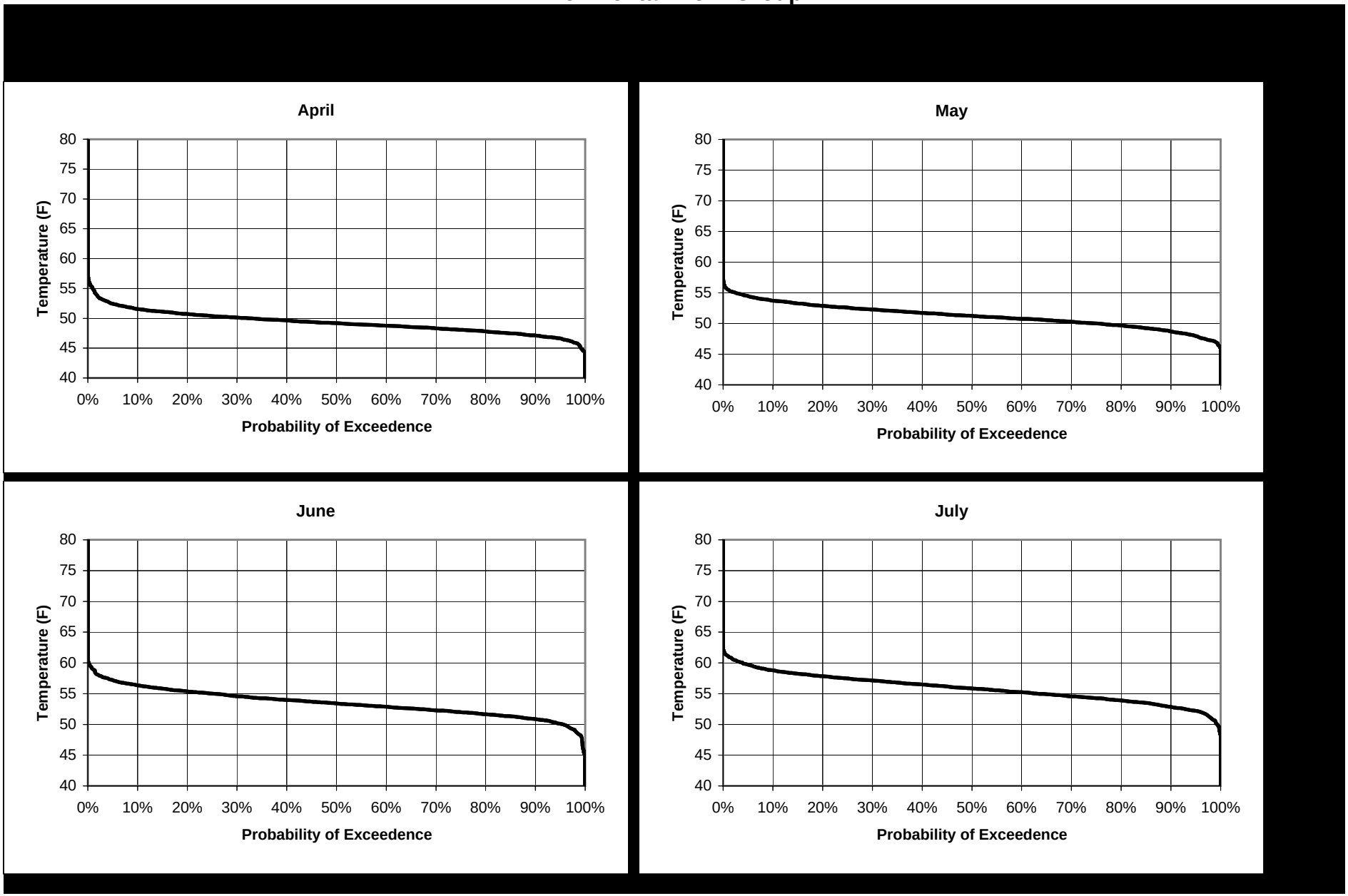



**Figure 2. Daily Average Temperature Exceedence Curves for Existing Conditions Benchmark Study Results for the Feather River at the Fish Barrier Dam (April-November).**

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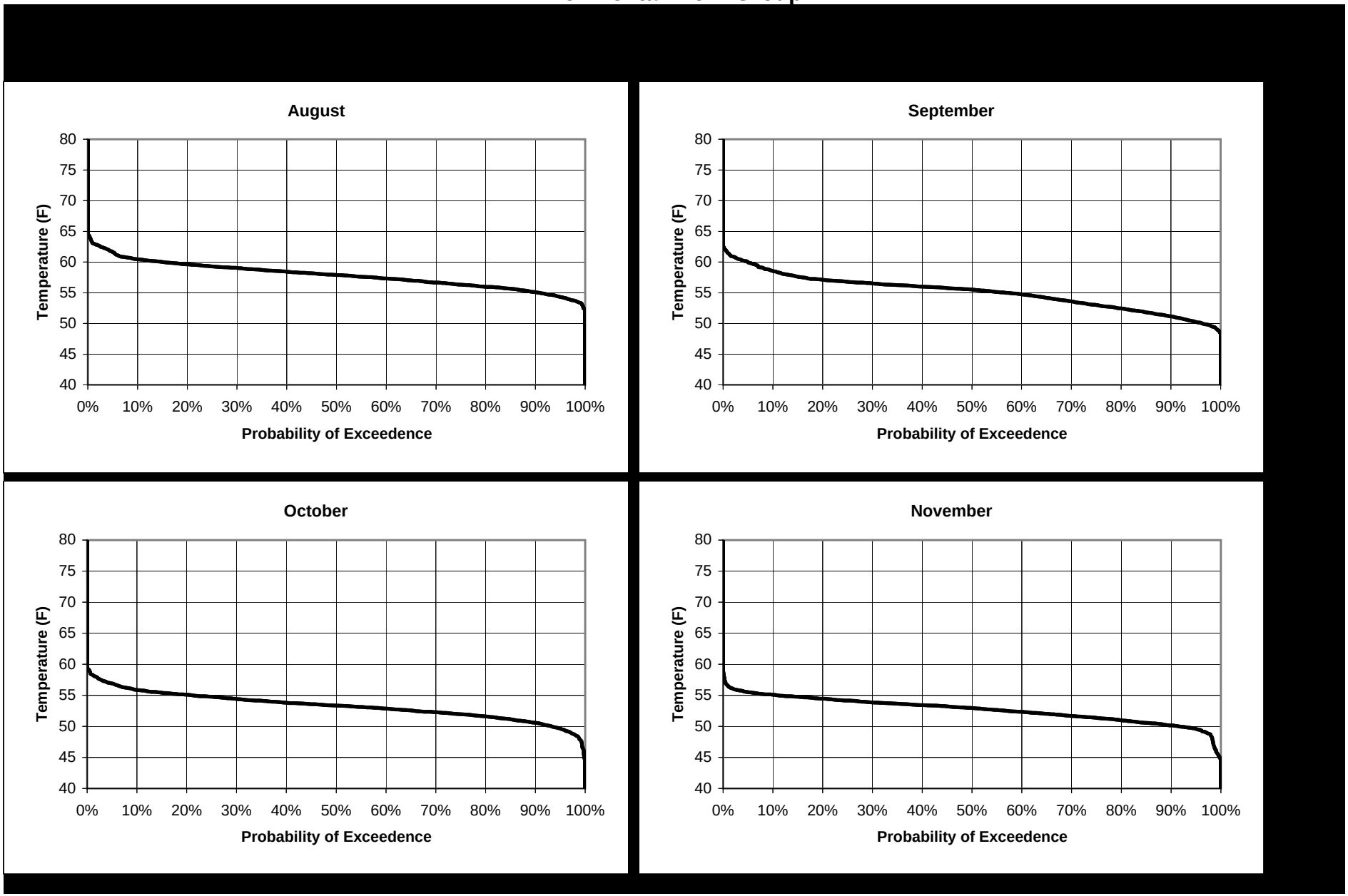


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**Oroville Facilities Relicensing Efforts**
**Environmental Work Group**
**Draft Narrative Report for Resource Action EWG-36**

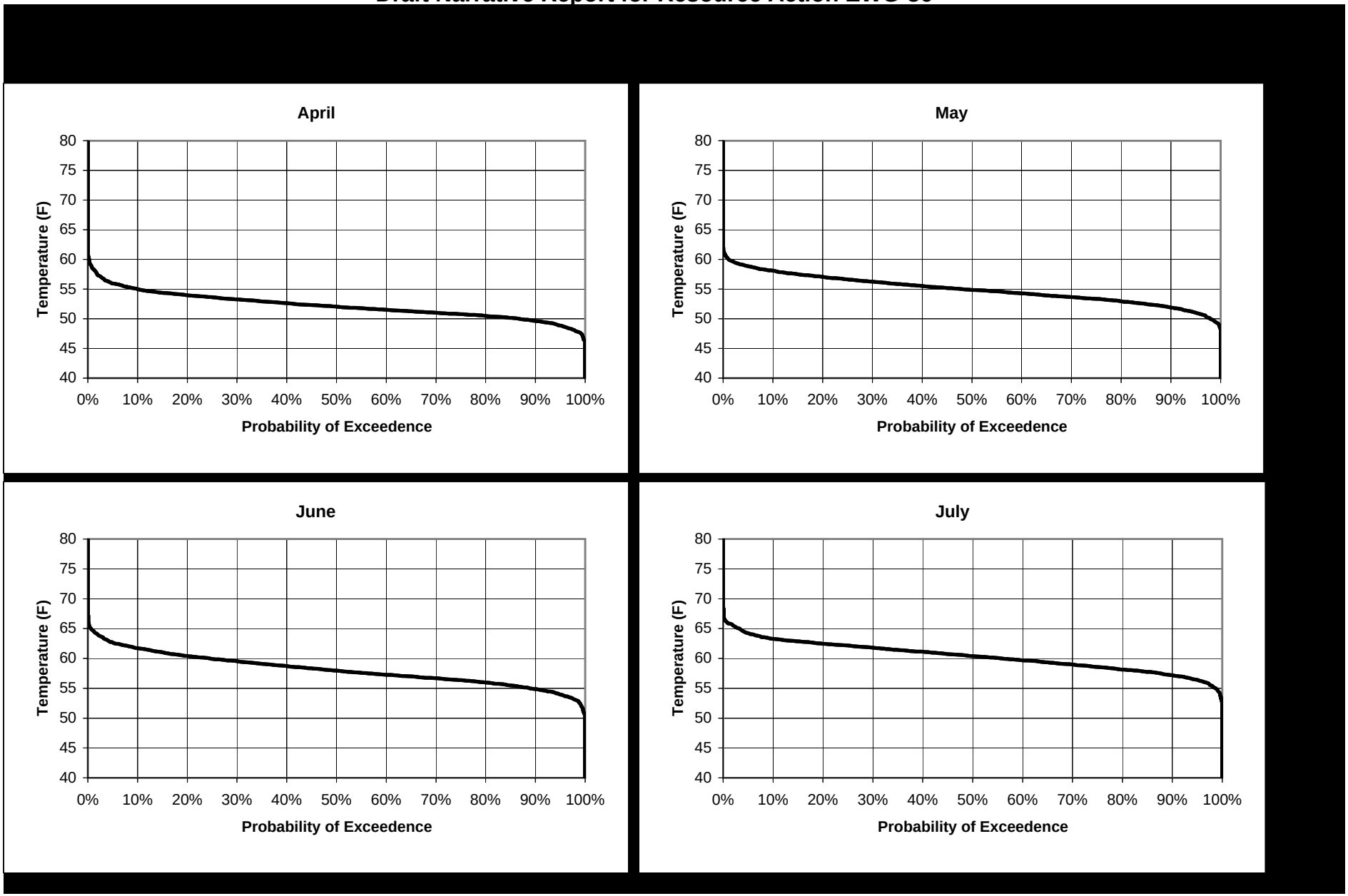
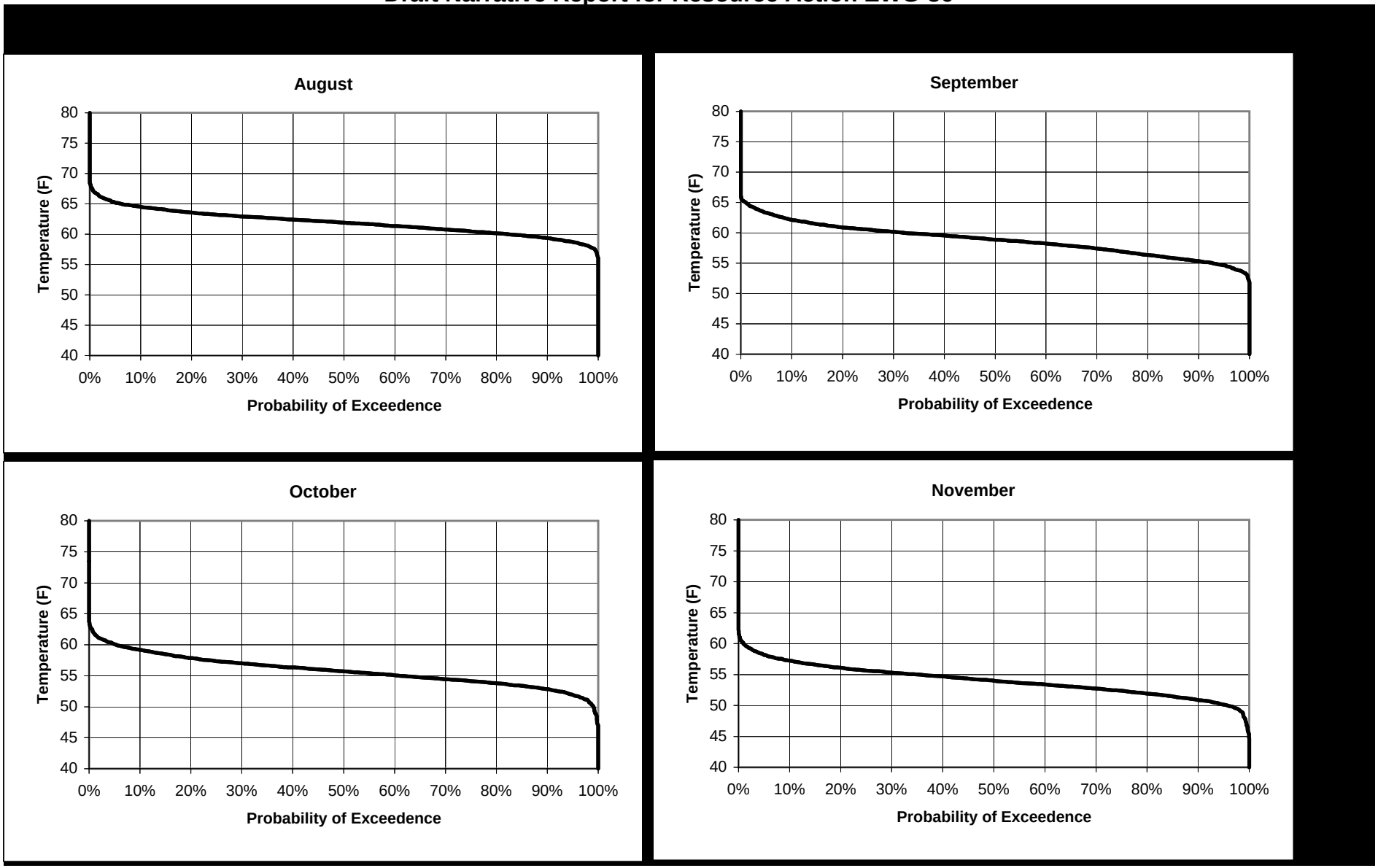



**Figure 3. Daily Average Temperature Exceedence Curves for Existing Conditions Benchmark Study Results for the Feather River at Robinson's Riffle (April-November).**

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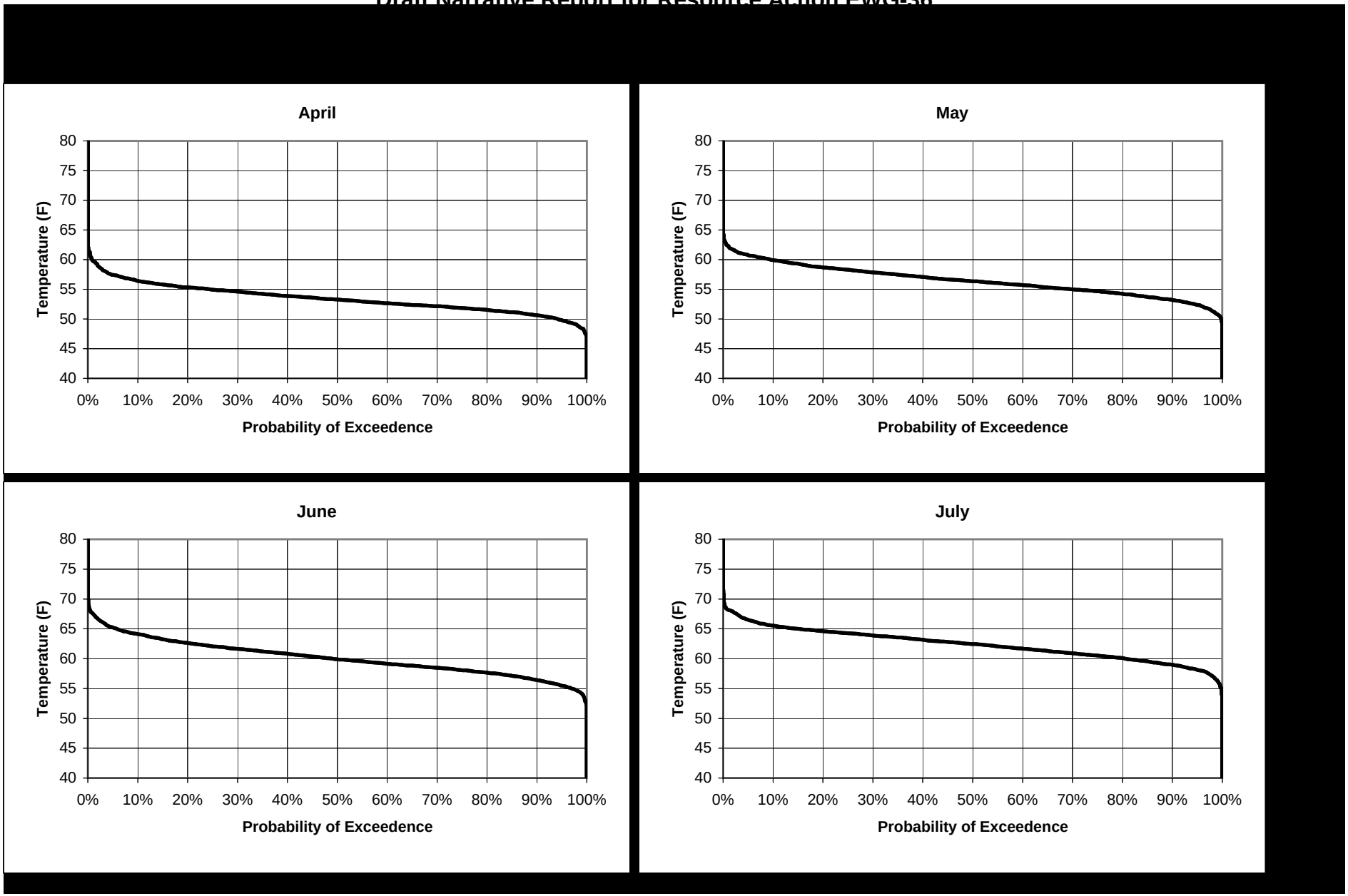


**Figure 4. Daily Average Temperature Exceedence Curves for Existing Conditions Benchmark Study Results for the Feather River Above Thermalito (April-November).**

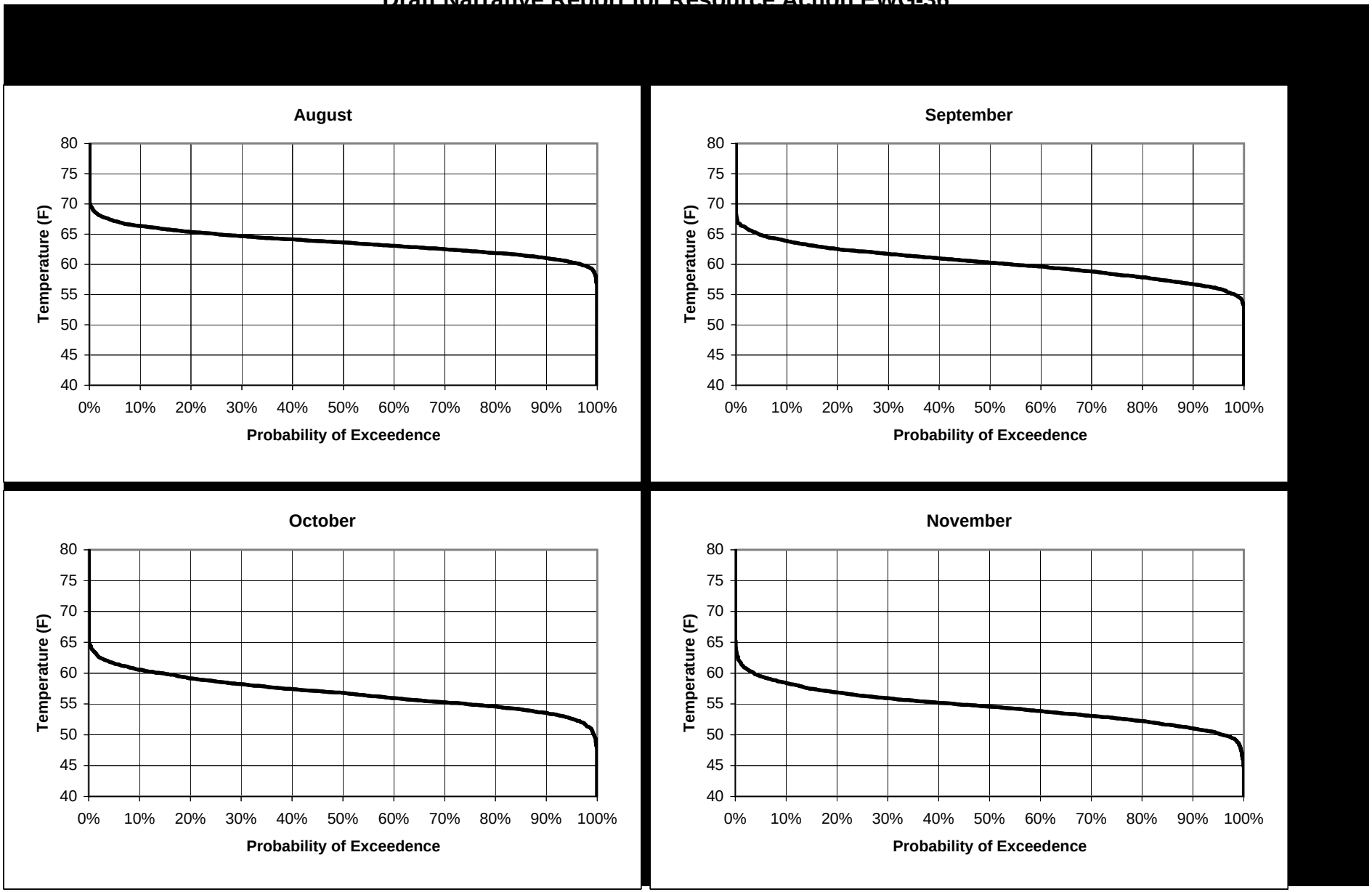


**Figure 4. Daily Average Temperature Exceedence Curves for Existing Conditions Benchmark Study Results for the Feather River Above Thermalito (April-November).**

**Figure 5. Median, 95th Percentile, and 5th Percentile of Increases per River Mile in Average Daily Water Temperatures for Two Reaches of the Low Flow Channel of the Feather River**